Fraunhofer
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NEWS 1.18

DDMC 2018, MARCH 14-15, BERLIN

LIGHTWEIGHT SKATEBOARD TRUCK

SIMULATION-BASED DEVELOPMENT

CUTTLEFISH DRIVER AVAILABLE

Rapid.Tech 2018, June 5-7

From **5 to 7 June** next year, the "3D printing family" will be returning to Erfurt to share their expertise for the **15th time** Rapid. Tech + FabCon 3.D is one of Europe's key information and communication platforms for Additive Manufacturing processes. It focuses on the latest developments in rapid prototyping, the manufacturing of end products using additive techniques, and how the technology can be transferred into mass production.

Both the specialist conference and the exhibition will once again showcase the latest innovations and applications in the field of Additive Manufacturing. The unique nature of Rapid.Tech + FabCon 3.D has been impressing exhibitors, visitors and participants alike for some 15 years now. The 14th event held back in June once again broke records, with both the exhibition hall and the specialist conference completely sold out.

RAPID.TECH
FABCON 3.D
International Trade Show + Conference for Additive Manufacturing

RAPID.TECH, ERFURT

BOOTH 2-311

JUNE 5-7, 2018

Visit us on our alliance booth!

Great Turnout for DDMC2018!

DDMC2018
Fraunhofer Direct Digital Manufacturing Conference

The 4th Fraunhofer Direct Digital Manufacturing Conference was held **March 14-15 in Berlin**. The six keynotes, 58 oral and 12 poster presentations in 17 sessions brought the **160 participants** ahead of the game on all aspects of additive manufacturing, including pre- (software, powder) and post-processing (automation, hybridization).

A real highlight was the international character of the conference and the representation of all stakeholders in additive manufacturing. Over **25 different countries** were represented and almost equal numbers of industry and academia participated, leading to new synergies that gave the conference floor networking and social program an extra buzz, with everyone leaving the conference with new enthusiasm, inspiration and contacts in this exciting field. Another highlight was the **conference dinner** at the Two Buddhas restaurant, which proved a perfect opportunity to catch up with colleagues in a more relaxed atmosphere.

Our congratulations go to the winners of the **Best Paper Award** (Andreas Bauereiss et al. for their paper on "Simulation Aided Material Development for Selective Beam Melting Processes") and **Best Poster Award** (Irina Smolina and her colleagues from the Wroclaw University of Science & Technology, Poland, for their work on "New Horizons of Mechanical Properties of Heat-treated CoCrMo-6RE Produced by Selective Laser Melting") – **well done, everybody!**

Special thanks go out to all those who helped make the DDMC conference such a success, including the keynote speakers, presenters, session chairs, committee members, sponsors and our tireless organizing team.

www.ddmc-fraunhofer.de
info@generativ.fraunhofer.de

Keynote Speakers DDMC 2018 were among others

Prof. Chua Chee Kai
Singapore Centre for 3D Printing, Singapore

Andreas Graichen
Siemens Industrial Turbomachinery AB, Sweden

Prof. Dietmar W. Hutmacher
Queensland University of Technology, Australia

FRAUNHOFER AM ALLIANCE AT FORMNEXT

Minister for Economic Affairs visits alliance booth

The Fraunhofer Additive Manufacturing Alliance attracted again many interested visitors to its booth. One highlight was the visit of the German Federal Minister for Economic Affairs, Brigitte Zypries.

The Minister for Economic Affairs, Brigitte Zypries, was also interested in the successful project for additive manufacturing of lightweight-optimized skateboard axles. (© Fraunhofer ILT)

At the joint booth of the Additive Manufacturing Alliance visitors of Formnext in Frankfurt am Main were able to experience versatile solutions for Additive Manufacturing, such as multi-material processing, additively manufactured, fiber-reinforced components and additive manufacturing of metal components.

The Federal Minister for Economic Affairs, Brigitte Zypries visited the Fraunhofer booth at the first exhibition day. On this occasion Dr. Bernhard Mueller, Spokesman of Fraunhofer Additive Manufacturing Alliance, presented her the latest developments in the area of additive manufacturing and 3D-printing and explained the shown exhibits at the joint booth. Mrs. Zypries was especially impressed by the lead exhibit, a large sized refined metal grid cube, developed by Fraunhofer EMI and additively manufactured by means of laser beam melting technology. She was also impressed by the lightweight skateboard axles of the student Philipp Manger from Jena, which were structurally optimized and additively manufactured by Fraunhofer IWU. The Minister was also fascinated by the human anatomy model of Fraunhofer IGD, which was manufactured for the exhibition in 4D printing.

For the Fraunhofer Additive Manufacturing Alliance, the visit of the Federal Minister for Economic Affairs was a successful start of a very prosperous exhibition appearance. Many visitors were infected by the ideas of Fraunhofer for additive manufacturing and the Fraunhofer researchers were able to establish numerous new contacts with interested industry representatives at the exhibition, who want to access and establish additive manufacturing for their respective companies.

With a record attendance of 21,492 visitors in 2017 Formnext is the international leading exhibition and conference in the field of additive manufacturing and the next generation of intelligent, industrial production.
It is the platform for companies from all over the world for issues of design and product development, industrial tooling, production solutions, quality management and measurement technology, as well as for leading providers in basic materials and component design.

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AWARDING CEREMONY

A grant of 10 million EUR was allocated to Fraunhofer IGCV´s MULTIMATERIAL CENTRE in the city of Augsburg, Germany

Bavarian Secretary of State Ilse Aigner (center) highlights the importance and emphasis the commitment to the production and innovation hub Augsburg (Germany) when presenting the grant to Prof. Dr. Alexander Kurz (Board member of Fraunhofer, right) and Prof. Dr.-Ing. Gunther Reinhart (Managing Director of Fraunhofer IGCV, left). (© Fraunhofer IGCV)

The grant awarding ceremony took place on December 8, 2017 at Fraunhofer IGCV where Bavarian Secretary of State for Economics and Technology Ilse Aigner formally presented the 10 million Euros. In her speech she underlined the importance of additive manufacturing processes which account for the competitive edge of the manufacturing industry in Bavaria in particular as well as in Germany. "Bavaria is a globally recognized high tech location. Thanks to our innovative companies and research institutions we are the leaders, particularly in the field of production. We want to support this leading position and are therefore granting the 10 million Euro to the MULTIMATERIAL CENTRE in Augsburg."

MULTIMATERIAL CENTRE Augsburg

The MULTIMATERIALCENTRE Augsburg, placed at Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV, was started on July 1st, 2017. Research on multi material processing is being conducted across the fields of product development, process technology and the process chains. Particular attention is being paid to the processes laser beam melting, cold gas spraying and directed energy deposition.

Dr.-Ing. Christian Seidel, project head at MULTIMATERIAL CENTRE Augsburg, wants to lay the foundation to ensure Germany's leading role in metal additive manufacturing. The project aims to establish ways to additively manufacture components with integrated sensors and actuators. These components will consist of several metal alloys (metal/ metal components) or alternatively of a combination of metal alloys and technical ceramics (metal/ ceramic components).

Project overview MULTIMATERIAL CENTRE Augsburg:

Time frame: 07/01/2017 – 06/30/2022
Budget: 10 million EURO
Technological objectives:

1. Establish product development methods for multi material components (metal/ metal and metal/ ceramic) with integrated sensors and actuators.
2. Gain knowledge on how materials change and interact during additive manufacturing processes (laser beam melting, cold gas spraying and directed energy deposition DED).
3. Ability to integrate sensors and actuators in powder bed based additive manufacturing production processes.
4. Optimize DED Processes in multi material processing with integrated sensors and actuators.
5. Create a software chain to optimize part design (Design for Additive) for mechatronic multi material components.
6. Establish a quality management system for multi material processing.
7. Create corresponding concepts for production and factory planning.

Project´s advisory committee:
3M Deutschland GmbH | Cluster Mechatronik & Automation e.V. | Cluster Neue Werkstoffe e.V. | Concept Laser GmbH | EOS GmbH | Federal Mogul Friedberg GmbH | MAN Diesel & Turbo SE | MT Aerospace AG | pro-beam AG & CO. KGaA | Siemens AG | Universität Duisburg-Essen

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CUTTLEFISH DRIVER AVAILABLE

Cuttlefish driver available to all Stratasys J750 3D printer users

Figure 1: Cuttlefish turns complex models with multiple sub-parts and RGBA textures into 3D prints with highly accurate color and translucency. (© Fraunhofer IGD)

High-volume 3D printing is entering the next phase: At formnext 2017, Stratasys announced its open Voxel Print interface for the J750 full-color multi-material 3D printer. The J750 can now be used with Fraunhofer IGD's Cuttlefish printer driver, which has been successfully leveraged for past Stratasys projects.

Cuttlefish is a universal 3D printer driver developed by Fraunhofer Institute for Computer Graphics Research IGD. It uses scanned data or 3D models created by design and texture painting tools – and turns them into 3D prints with highly accurate color and translucency reproduction via Stratasys' J750 printer.

At the formnext 2017 trade fair, Stratasys unveiled the GrabCAD Voxel Print solution for its J750 3D full-color multi-material printer – "unlocking" the system for use with third-party software. Fraunhofer IGD's Cuttlefish interfaces seamlessly with GrabCAD Voxel Print.

"Fraunhofer IGD was one of our first GrabCAD Voxel Print users, allowing them to develop Cuttlefish to fully exploit the color and translucency capabilities of the Stratasys J750 full color 3D Printer," says Stratasys Education Product Leader Tomer Gallimidi.
The driver has demonstrated its effectiveness already: Award-winning animation studio LAIKA started using Stratasys' J750, Cuttlefish and Voxel Print more than two years ago on their next unannounced film. While the stop motion feature film is still in production, LAIKA has printed more than 80,000 faces (and counting) using Cuttlefish. Oscar® nominee Brian McLean, LAIKA's Director of Rapid Prototype, said, "Cuttlefish's handling of complex geometries and accurate color has afforded us a level of control in a 3D print we have only dreamt about until now. Combining Cuttlefish, Voxel Print and Stratasys' J750 has allowed us to create highly detailed colored 3D prints and extremely subtle facial animation." Now, all J750 owners will be able to leverage Cuttlefish for their tasks.

The latest version of Cuttlefish supports RGBA textures that contain both color and translucency information, ranging from fully opaque to fully transparent. The driver enables users to print multiple overlapping models, each with one or more RGBA textures.

Philipp Urban, Head of the 3D Printing Competence Center at Fraunhofer IGD, explains: "RGBA data based 3D models are supported by 3D file formats such as OBJ or WRL, and can be created by many design and texture painting tools. Furthermore, RGBA textures can be made or modified by popular image editing tools, such as Adobe Photoshop. Cuttlefish closes the quality gap between virtual design and its 3D-printed reproduction." These capabilities are evident in a printed human anatomy model formed from 28 sub-parts. Each of these is assigned a unique material, comprising over 425 megapixels of color texture data. Transparent parts of the model are created simply by modifying the RGBA data.

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Project T.O.S.T. shows the potential for lightweight hybrid designs in metal additive manufacturing

Extreme lightweight design can usually be found in areas of engineering like motorsports and aerospace. In this case, structural lightweight design was applied to a skateboard truck, which is used in the little-known extreme sport of downhill longboarding. In this sport, the skateboard weight and stiffness has great influence on the control and agility while riding at higher speeds.

Project T.O.S.T.

In the Project T.O.S.T. (Topology Optimized Skateboard Truck) a skateboard truck was specifically designed for metal additive manufacturing, in particular laser beam melting. Using the example of this component, the basic procedure and the potential of hybrid design for additive manufacturing (AM) are shown. In this context, hybrid design combines organic and lattice structures for an extreme structural light weight design. Additionally, "Design for additive manufacturing" (DfAM), which includes all freedoms and constraints from the manufacturing process, was consistently implemented from the beginning of the development.

A comparison of the optimized to commercially available conventional skateboard trucks reveals the potential for weight reduction by increasing stiffness. Moreover, the project also explores the development of a coherent workflow from concept to final production using different new software tools for generative design in interaction with the metal additive manufacturing process.

Organic form like a skeleton

Characteristic for this workflow is the use of generative design to copy nature on different levels of the design process as follows:

- using topology optimization to create an organic form like a skeleton
- using lattice structures to fill tubular and hollow structures for improved rigidity like in bones

And as a third important step the "Design for additive manufacturing" (DfAM) was applied from the beginning for a cost-efficient manufacturing and optimized part performance.

The project began as a private idea of the student Philipp Manger (EAH Jena), who quickly established connections to the Fraunhofer IWU and Autodesk. Both have supported him with software, testing and manufacturing equipment as well as AM know-how.

Two different designs

At the end, two different designs were finalized and manufactured. The first version was designed as a sandwich with a graded lattice core designed along the force path and a thin solid shell on the outside.

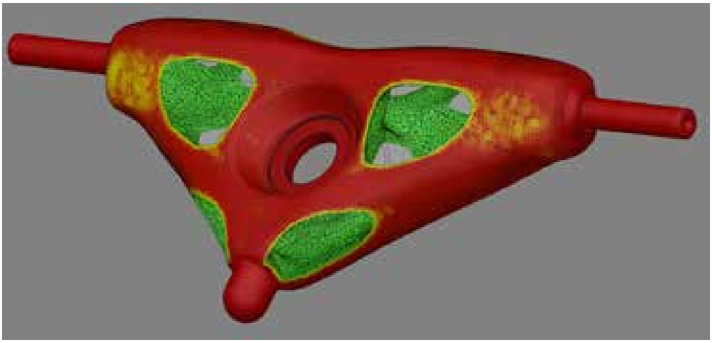

Figure 1: Topology optimization to create suitable geometry according collected load cases leading to 65 % volume reduction (©Philipp Manger)

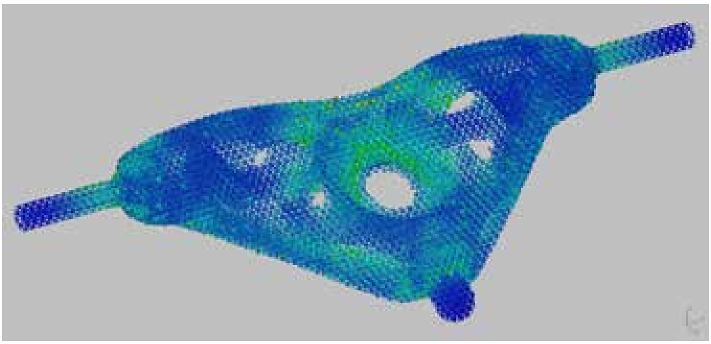

Figure 2: Graded internal lattice gaining another 60 % volume reduction (©Philipp Manger)

Figure 3: Testing of the manufactured prototypes under real conditions (sandwich version is shown) (©Philipp Manger)

The openings in the shell are positioned according to the topology optimization results and existing design constraints of the laser beam melting process. For the second version, a hybrid design with topology optimized organic shapes was hollowed and filled with a force tailored lattice core to further increase rigidity of the part. Regarding DfAM, part orientation during the additive manufacturing process as well as necessary support of downfacing surfaces was considered at an early stage.

Results

Overall, 25-32 % weight savings and 15-18 % increased rigidity were achieved. It took less than a year from first idea to test rides with the manufactured prototype trucks. In June 2017, Project T.O.S.T. got rewarded in two categories, design and best student project, at the 3D Pioneers Challenge (www.3dpc.io).

Furthermore, the project got nominated among five finalists of the TCT Consumer Product Application Award (www.tctawards.com).

A video clip about the project is available at: https://www.youtube.com/watch?v=8ko-Evn2y0AQ.

Figure 4: Hybrid version of the manufactured trucks mounted on a downhill skateboard (©Philipp Manger)

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Formulation of reactive inks: reactive inkjet printing of polyurethane foams

Novel fabrication processes are currently subject to a variety of research fields. Digital printing can be used to produce well-known materials in an innovative fashion. Therefore, Fraunhofer IGB focuses its research on inkjet printing as a manufacturing tool to individualize production processes.

Combining printing and chemistry

Combining printing and commonly known polyurethane chemistry has a high potential for future manufacturing. Currently, we are focusing on the production of polyurethane foams using two-component reactive inkjet printing.

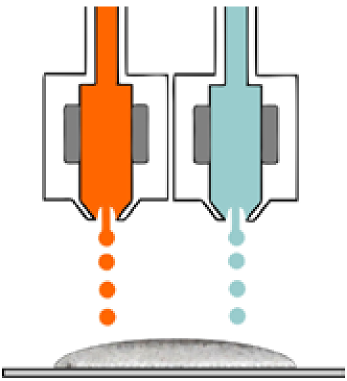

Figure 1: two-component reactive inkjet printing with Polyol and Isocyanate (© Fraunhofer IGB)

Two-component reactive inkjet printing

Here, two separate inks containing the reactive components are separately printed in a layer-by-layer procedure. The "polyol" ink contains a polyethylene glycol (PEG) as the main carrier combined with a glycerol ethoxylate "star-PEG" as the crosslinker. Furthermore, a foam stabilizing surfactant, catalysts, and water as the chemical blowing agent are present in the "polyol" ink. The second ink contains the pure isocyanate compound. Here, a hexamethylene diisocyanate-based ink is used to obtain porous polyurethane structures.

We found that our ink formulations were jettable using a 10 pL Fujifilm Dimatix printhead. Furthermore, microliter droplets that were placed on top of each other showed exothermic heat evolution as well as the corresponding polyurethane and polyurea band in FT-IR spectra. This confirms that the PU-reaction takes place even without mechanical mixing prior to the application.

Further information on the topic of reactive inkjet printing can be found in: . Mater. Chem. C, 2017,5, 6738-6744

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Additively manufactured sample holder for emissivity measurements of semi-transparent materials

The emissivity of materials is an important material value, for instance in the technical design of optical devices. Especially the determination of the emissivity of semi-transparent samples is a scientific challenge and requires a complex measurement setup.

New sample holder

One technological challenge is to guarantee a constant and homogeneous temperature field in the sample. Therefore Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin and the Physikalisch-Technische Bundesanstalt (PTB) developed a new sample holder with complex inner heating channels. Due to the complexity of this new design, the sample holders cannot be manufactured with classical machining operations. Therefore powder bed based Selective Laser Melting (SLM) process was used to manufacture the component from copper alloy CuCr1Zr. The sample holder was successfully assembled at PTB and will enter operation in 2018.

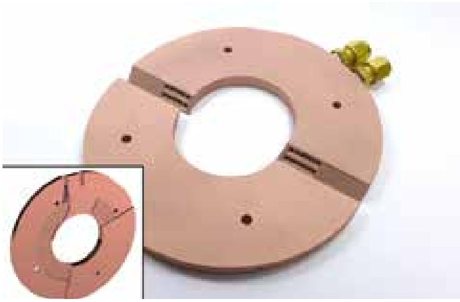

Figure 1: Specimen holder from copper alloy CuCr1Zr manufactured at Fraunhofer IPK (cutaway model) and CAD model showing bifilar executed heating channel design. (© Fraunhofer IPK)

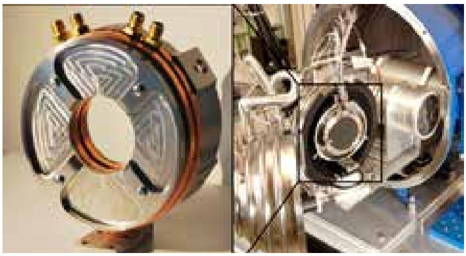

Figure 2: Left: Assembled specimen holder unit with additively manufactured copper alloy parts. Right: Emissivity measurement facility at PTB in Berlin. (© Fraunhofer IPK)

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Integration of electronic components in additively manufactured metallic parts

Integration of electronic components such as sensors can help to make operating systems more efficient. Real-time condition monitoring enables the engineer to plan for an on-demand maintenance, which shortens system downtime.
The classical manufacturing processes restrict the attachment of the sensors, because the geometry-generating manufacturing process has to be finished. The position of interest and the measuring position often differ, which can result in inaccurate measurement values.

The additive manufacturing processes make it possible to integrate the electronic component during manufacturing. Because of that, the engineer can choose the position, based on the measurement purpose.
A technological challenge is to prevent a destruction of the electronic components due to the high temperatures during manufacturing.

The Fraunhofer IPK in Berlin has developed component designs and production strategies to solve these challenges. Using the additive manufacturing technologies Selective Laser Melting and Laser Metal Deposition it was possible to integrate LEDs into a demonstrator successfully.

The investigations were carried out in the project "SiaB - Sensor Technology in Additive Components" of the Center for Digital Transformation.

Figure 1: Selective Laser Melting manufactured raw workpiece without electronic components (© Fraunhofer IPK)

Figure 2: Laser Metal Deposition to encase the integrated electronics (© Fraunhofer IPK)

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Metal Fused Filament Fabrication – New technology for metal 3D printing at Fraunhofer IFAM Dresden

The additive manufacturing process Fused Filament Fabrication (FFF) is already established as a technique in additive manufacturing of synthetic components and is widely used in both industrial as well as home applications. Now the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden has broadened the application range significantly by widening the material range to metal components, which had not been possible before.

Widening the material range

With this significant advancement, the institute can bring in its long-time knowhow in powder metallurgy into a well-known technology and, thus, combine tested processes with new materials. Here, the expert knowledge in the areas of Metal Injection Moulding and paste-based metal powder systems is implemented in particular.
During metal Fused Filament Fabrication, in a two-stage process, metal components are first printed and then finally solidified in a sintering process. In contrast to other R&D facilities, Fraunhofer IFAM Dresden offers its customers the complete process chain from filament fabrication to printing and up to sintering and component characterisation. In addition, green as well as sintered parts can be processed at the institute.

Research for component development

At the moment, the scientists are mainly producing components made of steel 316L; however, the technology is also suitable for all sinterable metals. In order to further extend the possibilities of industry-oriented research for component development, the institute is about to acquire the third printer with high process reliability and precision.

Figure 1: Printed and sintered gear wheel (© Fraunhofer IFAM)

Figure 2: Twisted box (stainless steel 316L, green and sintered) (© Fraunhofer IFAM)

The inexpensive equipment eases the further development of the process for commercialization with the goal of a low-cost production line of components in industrial quality.

Cooperation with industrial partners

Here, Fraunhofer IFAM Dresden cooperates with reputable industrial partners. With the participation in the SAB collaborative project "AMCC-Line" (Additive Manufacturing Complete and Compact), the integration of Fused Filament Fabrication for metals into an innovative prototypical production line is driven forward.

Due to the innovative metal Fused Filament Fabrication, Fraunhofer IFAM Dresden has further expanded its competence in additive manufacturing. In addition, further additive technologies like Selective Electron Beam Melting, three-dimensional screen printing and three-dimensional stencil printing are available to the customers to find a tailored solution to their questions.

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Additive Manufacturing of single- and multi-material components

Thermoplastic 3D Printing (T3DP) was developed at the Fraunhofer Institute for Ceramic Technologies and Systems in Dresden. This direct Additive Manufacturing (AM) process bases on the selective deposition of single droplets of particle-filled thermoplastic suspensions. The solidification of the deposited material for obtaining green components is due to the cooling of the wax-based binder system.

Figure 1: T3DP testing facility with four installed microdispensing systems (© Fraunhofer IKTS)

Dense microstructure

This shaping process is followed by a thermal treatment (debinding and sintering) to realize a dense microstructure and the final properties of the components. With this process, there are almost no limitations in terms of the type of material and powder used as well as the resulting component size. Thus, it is possible to 3D print components made of technical ceramics, glass ceramics, hard metals and metals. By utilizing multiple dosing systems which are moved over a fixed platform (Figure 1) in all three spatial directions, different thermoplastic suspensions can be deposited next to each other layer by layer to produce bulk material as well as property gradients within the additively manufactured green components.

Removing any non-solidified material

Unlike indirect AM processes, which selectively solidify material previously deposited over the entire layer, the T3DP process lacks the effort of removing any non-solidified material prior to the deposition of the next material, making it more suitable for the AM of multi-material components (figure 2 and 3).

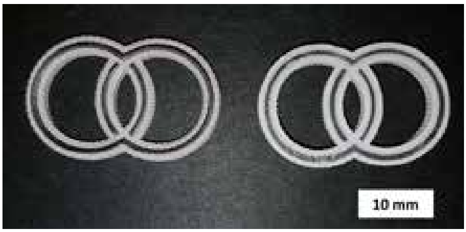

Figure 2: co-sintered zirconia component (black and white ZrO2) (© Fraunhofer IKTS)

The manufacturing of a multi-material component entails still challenges to overcome, in particular regarding the necessary thermal treatment after the AM process. In order to avoid critical mechanical stress during cooling, the coefficient of thermal expansion of all materials has to be approximately equal.

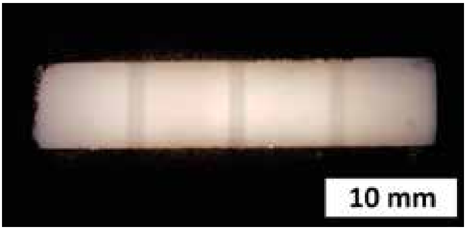

Figure 3: sintered zirconia component in front of a light spot with two different microstructures (darker areas: porous; brighter areas: dense)(© Fraunhofer IKTS)

Results and Outlook

However, the present results of the development of different feedstocks and corresponding thermal treatment process parameters show already the feasibility of the T3DP processing route. Ceramic powders must be mixed into a thermoplastic compound with a content of about 30% to 67% by volume which can be processed to dosable suspension (feedstocks). By means of the variation of the process parameters, droplet diameters of 200 µm to 1500 µm and droplet heights of 80 µm to more than 500 µm can be realized.

The resolution of the T3DP is thus between Fused Filament Fabrication (FFF) and Lithography-based Ceramic Manufacturing. The geometrical accuracy of a component produced by T3DP can be already improved by machining in green state, in order to match e.g. requirements concerning mounting dimensions and to save machining costs.

Further literature

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Start of EU project: Weld-seam characterisation in adaptive laser melting deposition

Wire-based laser metal deposition (LMD-W) allows the deposition of metal claddings to protect products from wear. Layer by layer, the wire is melted and deposited onto the device. To meet industry requirements for device tolerances and short production times, a highly stable process is required. Therefore, the Fraunhofer Institute for Production Technology in Aachen develops, in collaboration with six partners within the EU-funded research project »TopCladd«, an inline, high-precision optical metrology system that can be integrated coaxially into the welding head. The new system is designed to enable manufacturers to supervise and adaptively control the process of laser melt deposition.

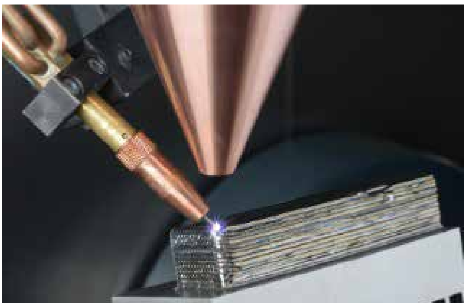

Figure 1: Within the project »TopCladd«, a high-precision optical metrology system is integrated into a welding head to characterise the weld seam of wire-based laser metal deposition inline. (© Fraunhofer IPT)

On 1 September, the Fraunhofer IPT started, together with international partners, its new project »TopCladd – Adaptive Laser Cladding for Precise Metal Coating Based on Inline Topography Characterization«. The aim of the project is the development of an inline process-monitoring tool including an adaptive control unit to improve quality insurance. The researchers use low-coherence interferometry (LCI) to realise a high-precision optical metrology system that measures the topography of the weld seam. To integrate the metrology system into the laser metal deposition process, a new welding head is being designed and adapted to the existing wire-feed drive. The generated process data will afterwards be analysed and used for simulations to allow the control unit to implement adaptive feedback. The fabrication of a demonstrator within the project's framework allows intensive testing of the new methodology.

Stability enhancement for resource-conserving process LMD-W

Initially conceived as a measure of wear-protection, wire-based laser metal deposition (LMD-W) comprises the layer-by-layer deposition of metal on a device by melting a metal wire with a laser. The process allows the deposition of layers that protect the device from wear and concomitantly improve the surface quality. Often, heavily used pieces can be repaired by LMD technology, thereby re-establishing their original functionality.

Compared to powder-based LMD processes, LMD-W has several advantages: The raw material can be used more efficiently. That saves ressources and energy, and thereby costs. Additionally, the wire-based process is more precise, which reduces expensive and time-consuming post-processing. The sample, however, is mechanically connected with the welding head, which incorporates the wire-feed drive and the laser. This connection influences the laser process and leads to deviations of the fabricated pieces outside of the design tolerances. To increase process stability, a common method is the increase of the laser spot size, which in turn increases the size of the heat-affected zone, leading to a higher material consumption.

From the project, the researchers expect a stabilisation of the LMD-W process, which, through automisation, will be independent from the user and the used wire material.

Project consortium

- Deltatec S.A., Ans (Belgium)
- Dinse G.m.b.H., Hamburg (Germany)
- Fraunhofer Institute for Production Technology IPT, Aachen (Germany)
- Geon X S.A., Gosselies (Belgium)
- Laserco S.A., Charleroi (Belgium)
- Precitec GmbH & Co. KG, Gaggenau (Germany)
- Quada V+F Laserschweißdraht GmbH, Schwerte (Germany)

The EU project »TopCladd – Adaptive laser cladding for precise metal coating based on inline topography characterization« runs from September 2017 to August 2019 and is coordinated by Fraunhofer IPT. The project is funded with 1.4 Million Euros by the Federal Ministry of Education and Research, within the framework of the programme »M-ERA.Net – flexible and market-tailored transnational funding in the area of material research«

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One for All and All for One

The current trend to realize hybrid machining solutions for additive manufacturing (AM), including pre- and post-processing, is driven by the potential of combining single processes in one machining system. Depending on the part characteristics, a significant reduction of manufacturing time and costs can be achieved. At the same time, the productivity of the AM process increases, especially in the case of high-volume part production. These benefits are interesting especially for industrial companies, which have to face permanent cost pressure, for instance in the field of turbomachinery or in the tool and mold making sector. However, nowadays such hybrid machining solutions still ask for intelligent and economical machine concepts, which can cover the complete process chain for hybrid AM part manufacturing.

Transfer into industrail application

To close this gap, research project OpenHybrid funded by the EU, grant no. H2020-FoF-2016-723917-OpenHybrid, has been designed to address the current technical and commercial limitations and to transfer such machining solutions into industrial application. Creating the groundwork for a more widespread adoption of AM by developing innovative hybrid machine concepts equipped with subtractive and additive manufacturing technologies, OpenHybrid offers new opportunities and applications.

To demonstrate this, two hybrid machining solutions – a hybrid 5-axis machine tool and a gantry system – will be setup within the 3-years project, which ends in September 2019.

Integration of processing heads

Therefore, one focus of the project is the development and integration of modular, changeable and compact processing heads, which will be integrated into these machining platforms. For the addressed AM processes, powder-based and wire-based laser metal deposition (LMD-P and LMD-W), the use of modular, changeable LMD processing heads will enable to switch easily between powder and wire feed-stock within the AM process, providing unmatched flexibility in terms of material selection and combination. Furthermore, additional specific hardware and software modules for pre- and post-machining as well as quality inspection of the parts can ensure consistent part manufacturing in the same setting. These modules are:

- Smart laser cladding head, incorporating temperature sensors and material feed sensing,
- Laser scanning head for heat treatment,
- Ultrasonic needle peening head for mechanical stress relieving,
- Cleaning head for contamination control,
- Non-destructive inspection modules

- CAD/CAM software modules for tool path planning

Beside the hardware design and development, different process chains related to LMD in combination with pre- and post-processing are currently investigated.

Figure 1: Wire-based LMD demonstrator (turbine blade shape) of titanium grade 5 (© Fraunhofer IPT)

The vision of OpenHybrid is beyond new parts production to offer also an innovative solution, which allows a very effective repair technique. Moreover, the process chains can be fitted to a diverse range of platforms (with minimal machine modification being required) as well as to existing machine tools in the future. Thus, the concept will strongly reduce the investment needed, while time it provides new capabilities to large and small companies at the same.

Project coordinator

MTC – The Manufacturing Technology Centre Ltd. (United Kingdom)

Project partners

BCT Steuerungs- und DV-Systeme GmbH (Germany)
Centro Ricerche Fiat Scpa (Italy)
Esi Software Germany GmbH (Germany)
Esi Group (France)
EWF – European Federation for Welding, Joining and Cutting (Portugal)
Fraunhofer Institute for Production Technology IPT (Germany)
GF Machining Solutions (Switzerland)
Gudel AG (Switzerland)
HMT – Hybrid Manufacturing Technologies Ltd. (United Kingdom)
Picasoft (France)
Siemens AG (Germany)
TWI Ltd. (United Kingdom)
Weir Group PLC (United Kingdom)

Further information

http://openhybrid.eu

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Multi-Material Laser Metal Deposition

Laser Metal Deposition (LMD) has already been introduced to several industrial branches. LMD serves the purpose of coating, part refurbishment and manufacturing functional components. The process is highly suitable for a broad material spectrum such as Fe-, Ni-, Co- or Ti-based alloys. Typical products comprise components for jet engines, turbines, tooling or medical implants.

Multi-material build-up

Fraunhofer IWS conducts research on the multi-material build-up by LMD with powder. By means of multi-material build-up, cost-intensive alloys are only used in highly-loaded component's areas whereas the remaining part is fabricated with less expensive compositions. The selection of combined materials strongly depends on both the requested thermo-physical and mechanical properties. In order to deposit material on a substrate, the powder material is blown into the process zone by a nozzle, partially preheated by the laser beam and finally reabsorbed in the laser-induced melt pool (see Figure 1). Several different powder materials mixed in-situ by an integrated powder-mixing chamber in the nozzle tip may be. Due to a continuous and locally controlled powder mixing, LMD enables new possibilities in Additive Manufacturing, e.g. depositing composite materials as well as in-situ alloying without any additional joining process.

Fig. 1: Powder-based multi-material LMD processing (© Fraunhofer IWS)

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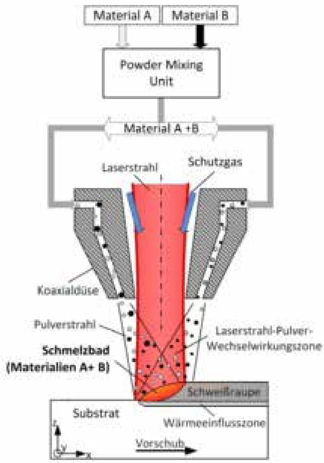

Fig. 2: Fraunhofer IWS multi-material processing head (© Fraunhofer IWS)

Material combinations such as Ti-Ta, Fe-Ta or Fe-Cu are highly interesting for industrial applications but cause several issues due to differing thermo-physical properties, poor miscibility or differing absorptivity. Therefore a transfer into industrial application requires a comprehensive understanding of process conditions (temperature fields, stress gradients), material properties (micro- and macrostructure) and occurring failure mechanisms. In order to solve these problems, Fraunhofer IWS investigates the following approaches for layer-wise multi-material build-up by LMD with powder:

- sharp material transition of binary material combinations
- graded material transition of binary material combinations

One major application is the multiple processing of tantalum and titanium alloys. Ti6Al4V exhibits excellent mechanical properties as well as biocompatibility and therefore belongs to the commonly used materials for fabricating implants. Due to better osseointegration properties and biocompatibility tantalum may be used for improving the integration of implants into the human body. Therefore combining tantalum and Ti6Al4V could lead to lightweight implants with outstanding mechanical properties and an increased lifetime. Joining Ti6Al4V and tantalum raises the issue of a large gap between the melting ranges of the materials. Because of tantalum's high melting temperature, simultaneous processing of these materials may cause local evaporation phenomena, which may lead to forming pores. Nevertheless, LMD successfully joined Ti6Al4V and tantalum by applying tailored process parameters and cooling strategies.

Graded transition

The joining of multi-materials may cause severe stresses within the transition zone due to differing thermo-physical and mechanical properties. Therefore a graded transition within the bonding zone depicts a promising approach for decreasing stress gradients and reducing cracking. Fraunhofer IWS manufactured a graded transition zone from Stainless Steel 316L to Inconel 718, while EDX analysis showed an accomplished linear transition.

Intra-layer multi-material processing

Fig. 3: Sharp material transition Ta/Ti6Al4V (© Fraunhofer IWS)

Aside from the layer-wise multi-material processing, an intra-layer multi-material processing of metal matrix composites constitutes another promising approach. Such composites are typically made of a low-melting metal matrix (e.g. Ni) containing ceramic particles or fibres with a high melting temperature (e.g. TiC). For example, TiC-Ni compounds may be used in high-temperature structural applications, such as automotive, aerospace and a wide range of industrial operations related to cutting, rolling or stamping.

Potential of this approach

The broad material combination range that LMD allows to process shows the enormous potential of this additive manufacturing approach. Investigations of further material combinations, such as Fe and Ti based alloys, are expected to highly benefit the improvement of industrial applications, especially in the aerospace and energy industries. However, metallurgical incompatibility, undesired local in-situ alloying phenomena and varying thermo-physical properties still belong to the unsolved challenges for this manufacturing approach which shall be overcome in future research.

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Hybrid Additive Manufacturing of electrical microsystems

Fig. 1: NextFactory Machine (left) and its integrated modules (right): Inspection, assembly, curing and 3D-printing (from left to right) (© Fraunhofer IPA)

Manufacturing of electronic circuits has strong geometrical restrictions due to established PCB-based manufacturing methods. Fraunhofer IPA presents a multi-material 3D printing process, which allows direct integration of freeformed conductive paths and electronic components inside a 3D printed part. The structures are manufactured with inkjet-printable materials compatible with the needs of electronic applications. In direct combination with micro deposition and assembly technologies, the 3D printing process is integrated in an automated machine setup at industry standard. The process and the machine was developed in the EU funded project "NextFactory" in collaboration with eleven partners.

Modular Machine Implementation

In order to empower industry to manufacture individual electrical microsystems additively, an automated and highly flexible manufacturing process chain is required. During the project "NextFactory", a machine was developed that meets all those needs (Figure 1). This platform, provided by the Suisse company Unitechnologies, is a suitable environment for direct interaction of four different modules that can be easily integrated and exchanged due to standard interfaces. The processes of the integrated modules can be configured by the operator into one strongly interwoven and automated process chain, adapted for the production of micro-mechatronic systems. The overall system is the basis to manufacture electronic devices by means of additive manufacturing.

Currently, process modules for 3D printing, precision-assembly, micro-deposition, curing and inspection are integrated. The 3D printing module has been developed to print dielectric, conductive and support materials. In interaction with the assembly module, it is possible to integrate discrete components like integrated circuits, resistors or even

Fig. 2: Printing system containing 3 printing units, 2 UV-led light sources for pinning and a flattening unit (left); detailed bottom-view of printing unit (right) (© Fraunhofer IPA)

silicon dies into the printed structure. With the inspection module, the position of the components can be detected as well as their position inside the printed structure. By that, it is also possible to detect printing errors (e.g. intermittent tracks, deviations from design). All measurements are automated to make a 100% quality control available. The curing module contains three different systems (UV curing, NIR sintering, IR heating) to cover the different requirements of conductive and non-conductive materials.

3D Inkjet System

The inkjet-based printing module (Figure 2) is designed in a modular way, containing several units for a specific purpose:

- Three Printing units: Each unit consists of a cartridge, four printheads and the required electronics for controlling temperature and pressure and to provide the printing data. Depending on the material needed, different printheads can be integrated. For dielectric, where a lot of material needs to be applied to guarantee a fast printing process, a Fujifilm Dimatix Inc. SL-128 printhead with a nominal drop volume of 80 pL´s used. For the conductive material, where small drops are needed to realize high resolution, a Fujifilm Dimatix Inc. QS256-10 with a nominal drop volume of 10 pL is integrated. Four printheads are prepared for each material, which allows four times higher printing resolution of up to 400 DPI (Fujifilm Dimatix, Inc. QS-256 with 100 DPI native resolution) or 200 DPI respectively (Fujifilm Dimatix, Inc. SL-128 with 50 DPI native resolution).

- UV LEDs: Partial curing of dielectric material right after printing is done with an UV LED array. This results in a increased accuracy and edge-steepness. The latter is especially important to form precise cavities for the integration of discrete components.
- Levelling unit: The defined distance between this unit and the building platform resp. the surface of the printed part allows the adjustment of a defined height of each layer.

Fig. 3: 3D multi-material structures manufactured with the NextFactory approach (© Fraunhofer IPA)

This printing module in combination with the integrated micro deposition technologies is the basis for 3D freeform printing with a wide range of different functional materials. Inkjet technology ensures effective processing with process-optimized materials, whereas micro-deposition allows integration of market-available standard materials, like conductive glues or pastes.

With the presented approach, 3D multi-material structures with integrated electronic components have been manufactured. A test structure is shown in Figure 3. It proves that the process approach enables the automated integration of conductive paths and even components inside a 3D printed microsystem. This is different to many approaches like MID (moulded interconnected device), where conductive patterns and components are applied only on top of a 3D substrate.

Additive manufacturing of functional components

Currently, the shown test structures were printed as proof of concept. But based on the professional machine setup, it is planned to manufacture enhanced products with increased complexity regarding shape and functionality. The range of applications, where electronic functionality is needed in customized products, includes medical devices like hearing aids, sensor applications for specialized measurement equipment as well as customer-specific small-series of system-in-package-devices used in a wide range of different applications.

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Simulation-Based Development of the Design of an Innovative Control System for an Additive Manufacturing System

In a collaborative project, Fraunhofer IFF is working on the development of a control system and simulation for demonstrator system accompanying development. The components of the innovative control system design include component control, motion planning and machine monitoring and operation. In this sub project, the simulation will be coupled with the machine controller (PLC, robot control by a real-time interface) and a safety specification that prevents collisions in work spaces (eliminating incorrect machine states). Furthermore, workpieces and materials will be incorporated in all of the operations and the real-time capability of the models created will be demonstrated under real conditions.

Software tool VINCENT developed by Fraunhofer IFF

The integrated simulation and software tool VINCENT, developed by Fraunhofer IFF, is being used to develop the control system for complex manufacturing operations (Fig. 1). This new integrative approach to motion planning and event simulation makes it possible to test geometry and function before manufacture of the system commences. Machine and structural elements as well as the controller, assemblies and media can thus be developed and optimized in parallel. Connecting the virtual model of the system with the real control system online makes it possible to identify potential collisions between different system components and the complex part being manufactured before a task is executed. Both short movements and complete manufacturing programs lasting several hours can be tested in advance. The software tool interconnects established systems and standards (generating a program code compliant with IEC61131-3) and easily imports CAD data (STEP files).

Rapid collision detection

One of VINCENT's major strengths is its rapid collision detection utilizing detailed CAD surface data without distorting bounding geometries and its capability to analyze the range of motion completely and verifiably by generating the safety zone for every one of the system's components.
The efficient program reliably and completely transfers know-how from design engineers to control engineers. Sequences in the machine are defined easily from start to finish by using established standard formats to exchange data.

Outlook

As the project proceeds, Fraunhofer IFF will modify and optimize the control system modules and the respective technical specification of the electrical components (drives, sensors, control loops, etc.), factoring in the extruder's final gantry design and the insert handling elements. Another important objective is reliable detection of any potential collision zones and collision control in real time.

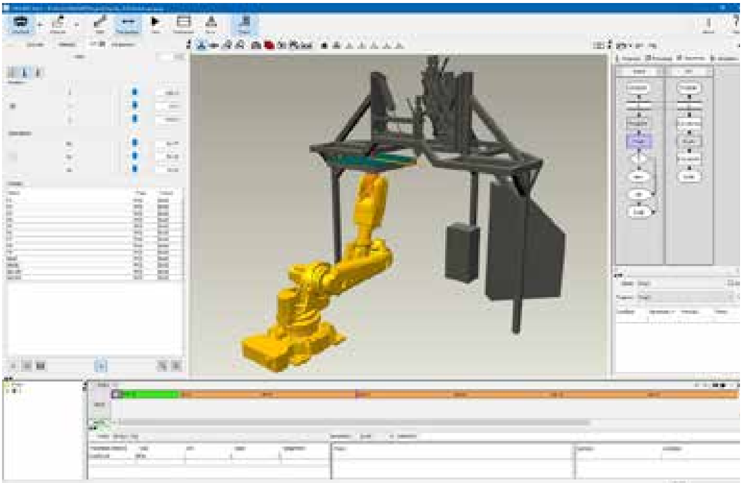

Figure 1: Simulation-based development with VINCENT (© Fraunhofer IFF)

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ONE TOPIC – 18 INSTITUTES – ONE ALLIANCE

Fraunhofer-competence in Additive Manufacturing

The Fraunhofer Additive Manufacturing Alliance integrates eighteen Fraunhofer institutes across Germany, which represents the entire process chain of additive manufacturing.
It includes five research areas like engineering (application development), materials (synthetic material, metal, ceramics), technology (powder-bed-based, extrusion-based, print-based), quality (reproducibility, reliability, quality management) and software and models.
Aim of the alliance is to advance applied developments and start trends in additive manufacturing.
Many years of experience from national and international industrial assignments as well as research projects form the basis for us to develop customized concepts and to handle complex tasks. The Fraunhofer GENERATIV Alliance is aimed at sectors such as automotive and aviation, but also biotechnology, medical and microsystems technology as well as mechanical and plant engineering.

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Cover Photo: Testing of the manufactured prototypes under real conditions